Operation and Planning of Power Distribution Systems
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Lecture - 31
Concept of Microgrids

So, in my last lecture, I started a new module in which I was discussing about distribution systems with distributor generation ok. And in my last lecture I basically focused on the definition of distributed generation and also its impact of the placement of distributor generation into distribution system. Now this impact is studied in view of power loss reduction or the change in power loss or and also the change in node voltages.

And that might be a sometimes over voltage, sometimes under voltage conditions, all those things, and also I discuss the concept of hosting capacity ok. Now, in this lecture, I will basically move on to another concept in which the placement of distributed generation is involved that is called Microgrid.

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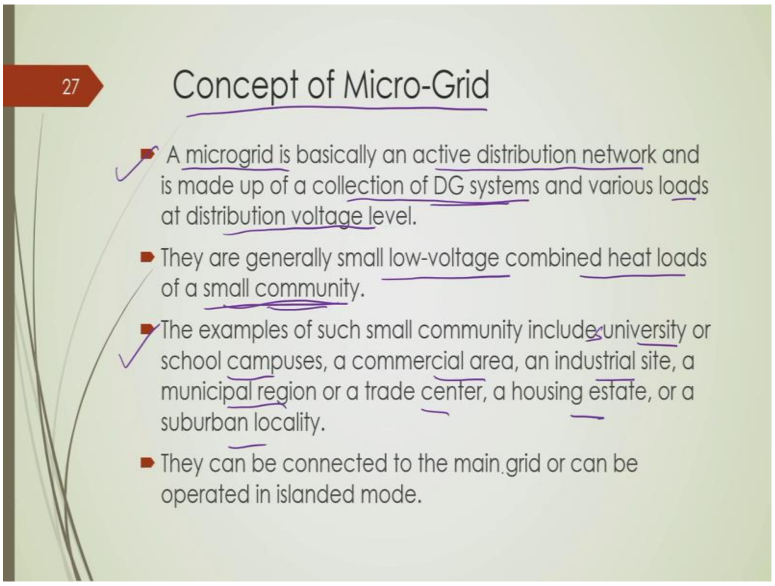

So, basically I will start with the concept of microgrid in this part of the lecture. Then, subsequently I will discuss on two most important or two mostly used type of distributed generation. One is called wind energy conversion system, another is solar photovoltaic energy conversion system.

These two are the major players in renewable energy source worldwide. And there, we have seen that these two types are growing very fast worldwide, so as in our country in India ok. So, in this, the concept of microgrid is, although this is not a standardized definition as I gave you this definition of this distributed generation in my last lecture, but microgrid is another domain of research in which many people are involved with and there are lots of research papers getting published every year ok. So, I will not discuss each and every component of microgrid, but I will basically focus on what is microgrid and how it is embedded or how it is connected to a typical distribution network ok.

In fact, what is happening inside this microgrid? What are the different aspects? Those things I will not discuss, I will rather give an overview on different challenges, different advantages of using microgrid and so.

So, a microgrid according to this definition, again this is I took from Turan Gonen book, a microgrid is basically an active distribution network and it is not an active distribution network that is it is embedded into an active distribution network and it is made up of a collection of DG systems, a collection of distributed generation systems and various loads at distribution voltage level.

What do you mean by distribution voltage level? That is similar to the utilization voltage level, that the voltage level at which the customer is getting power or energy from the utility ok. So, that is naturally that they are connected to small low voltage distribution networks. Possibly 400 volts 3 phase networks and it works with combined with heat and load. In fact, this is another form of microgrid where both heat and power are generated and they are being supplied to the customers ok.

And this is very useful particularly those areas where we have a very very chilly winter, chilly winter ok. Now the example of such small community actually this microgrid provides supply to a very very small community consisting of a few numbers of loads and generation; loads are also local.

So, therefore, it is something that whatever this small DG units they generate all this generation is fed to this local loads. And if we have if there is any excess or deficit generation then they exchange with the usual distribution network and thereby they exchange to the usual power grid ok.

Now, this small community we are talking about. So, microgrid supplies energy as well as heat to a small community and this small community includes university or school campuses, commercial area, small industrial site, small part of the municipal region, or a trade center, housing estate or suburban locality.

They can be connected to the main grid and operated or can be operated in islanded mode. But basically we will be concerning on grid connected microgrid because ultimately our theme is to understand their impact on distribution systems ok.

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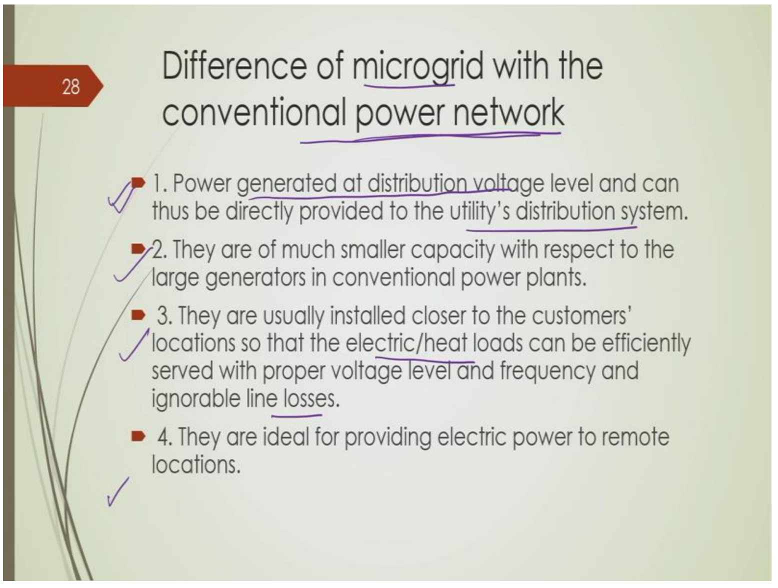

Now, what is the difference between microgrid and conventional power network or conventional distribution network? First of all, power is generated in distribution voltage level. In fact, no power is generated in distribution voltage level. You have seen conventional power network, generation voltage level is something different; then transmission voltage level is something different. Then we have sub-transmission voltage level, then distribution voltage level.

And also in distribution voltage level, we have primary distribution voltage level and finally, utilization voltage level that is secondary distribution network voltage level. But, here in microgrid, its generation is in distribution voltage level particularly utilization voltage level. And therefore, they can be directly connected to the utility's distribution system. They are of smaller capacity with respect to conventional generators; it is obvious.

They are closer to the customers' location and therefore, the electric or heat which is being generated can be effectively supplied to the customer with reduced losses, both losses. Here losses stand for both electrical losses or energy losses as well as losses in heat. They are ideal for electric power to remote location as well. So, for remote location where we do not have the access of conventional power grid we can supply them by forming a community microgrid.

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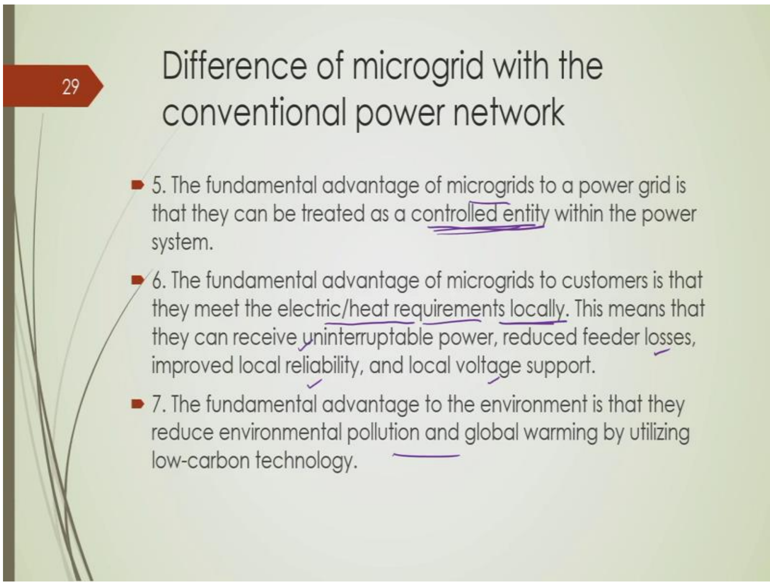

And of course, this remote location generally located in such places where we have either the availability of wind or availability of solar power. So, we can build a community microgrid utilizing these two main types of renewable energy sources and you can supply them. Now the advantage of this microgrid is to, "they can be treated as controlled unit entity".

So, since they are located within a very small geographical area, very very microlevel geographical area maybe within a particular building or within a particular small residential complex, s, control ability is much higher ok. So, it is possible to control all these quantities within this small geographical area. Now, this fundamental advantage of microgrid is, 'they can meet this heat and electricity re requirement locally this is already talked about'.

And also they can provide uninterruptable power with reduced losses with higher reliability and better voltage support which all these things are obvious. Because as you know, generation is in vicinity of the load and load is in vicinity of the generation.

So, there is very very small amount of energy power losses or energy losses which will take plac,e which will take place. Because, there is no as such transmission and distribution lines required here. But this microgrid is to be connected to the distribution system, I will come to that.

Now another advantage is that, you can reduce this pollution because if you can use or utilize this renewable energy source there within a local network we can reduce of course, this global emission.

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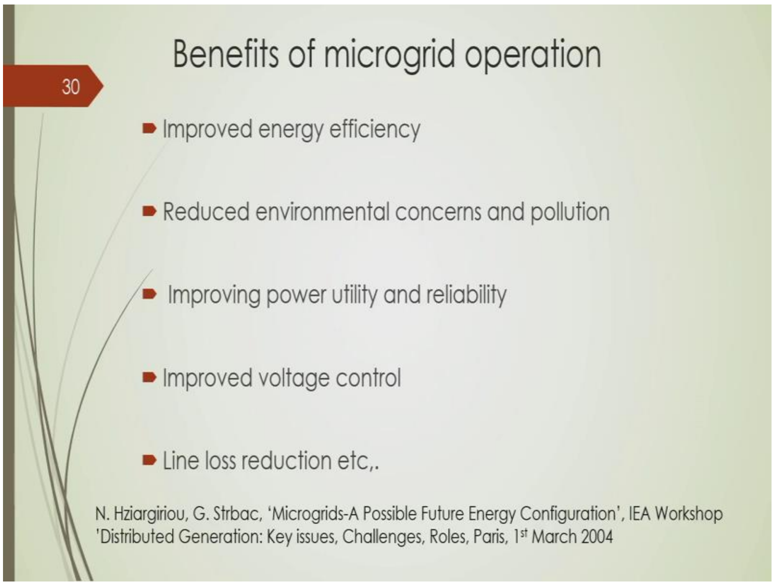

Also we can improve energy efficiency because of lower losses and pollution we are talking about. Again reliability, controllability, line losses, reduction, all these things are talked about.

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And therefore, there are some fine economic benefits as well. One is reduced amount of operational invest investment cost. Because there is no transmission and distribution cost involved for those loads who get power from this microgrids. And so therefore, cost saving is possible, quality of service can be maintained and reliability would be higher which is again talked about.

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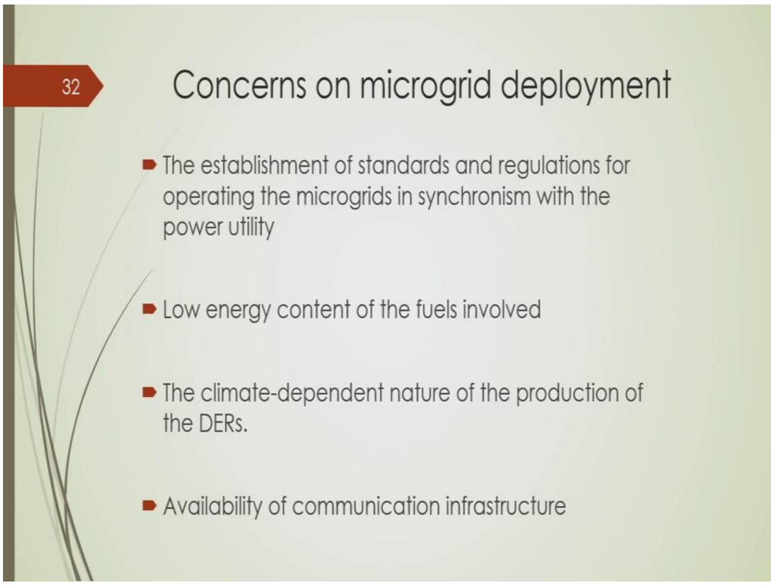

But there are some concerns, some challenges of deployment of microgrid. One is of course there is a less available standard and regulation ok. So, with time, slowly these standards are being developed. But till now, this is one of the challenge and energy contents of the fuel which are basically for renewable energy sources are small.

Energy content is small and climate dependent nature of the generation and that is why they are intermittent or they are having variable generation and availability of communication infrastructure which needs to be built ok.

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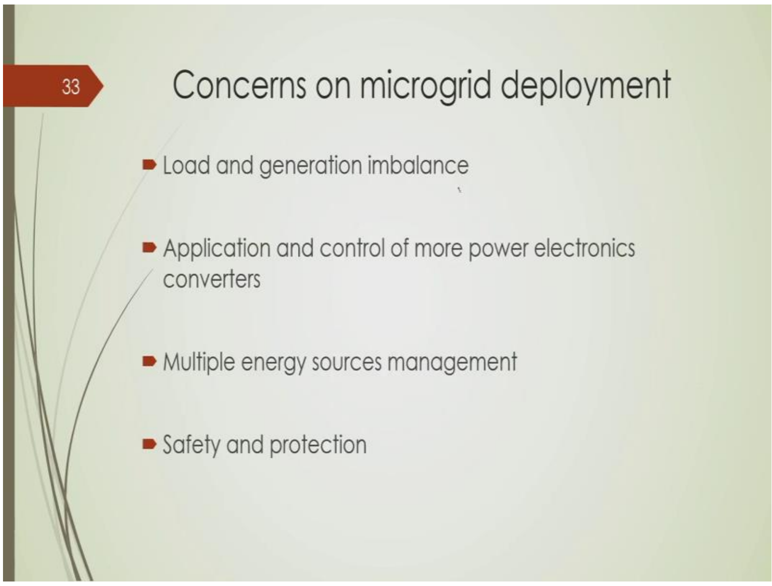

So, another major challenge is to meet this imbalance of load and generation. Particularly when this microgrid op will operate in islanded mode; islanded mode means it will disconnect from the conventional grid and it will operate independently with its own generation to supply its own load ok.

So, during that moment load generation and load imbalance will be a challenge. But if it is connected to the grid then this is this challenge will not take place. Because there will be no challenge because we can, obviously, get surplus or deficit power from the grid to import and export. And we can have this application of more power electronic converters also energy management is another challenge and protection.

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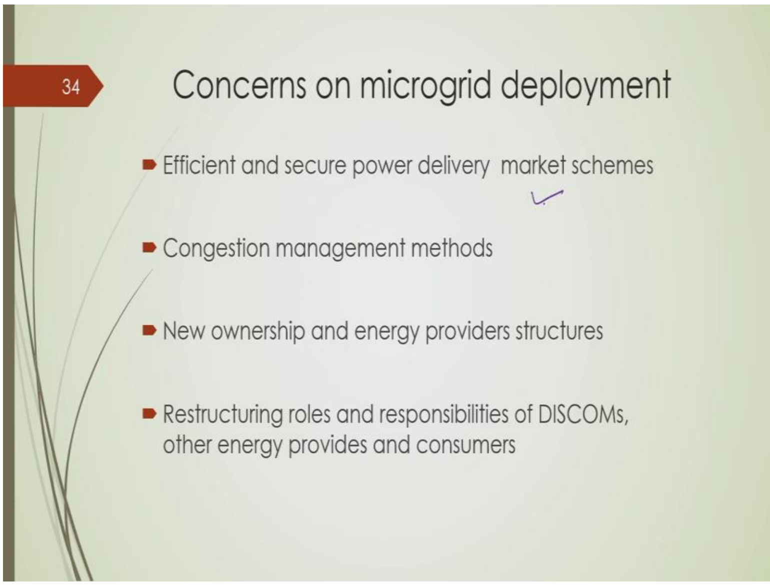

And also revising market scheme, congestion management which is similar to this imbalance, but it makes sometimes some lines overloaded. So, that is another challenge and also ownership and energy providing structures.

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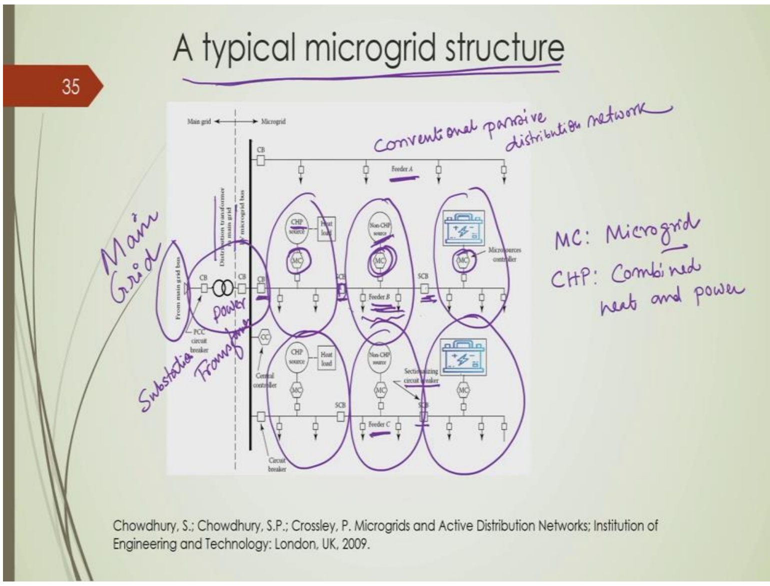

So, this is here a typical microgrid structure is shown in this figure; look at this figure very carefully. So, here we have this main grid, this is our main grid ok. So, we have a power transformer here, this is power transformer and then this is basically substation. This is where we have this power transformer and the bus bar arrangement to feed the load. And here we have 3 feeders; one is feeder A, another is feeder B, another is feeder C.

Now, feeder A, it is a conventional type of distribution network. So, this is a conventional passive distribution network. So, there is no distributor generation integrated with that ok, but in feeder B and feeder C you can see we have DG as well as community microgrid. So, here we one have MC stands for here microgrid MC stands for micro grid.

So, this is one microgrid, this is another microgrid, this is another microgrid ok. So, this microgrid is having combined heat and power. So, CHP is basically combined heat and power ok and this is non CHP type of DG. So, these microgrids have their own loads which are shown over here in this particular feeder section and they have their own generation.

So, if you disconnect this you know SCB; SCB is circuit breaker. So, here we have a sectionalizing circuit breaker. So, here we have main circuit breaker which is located in the substation and we have two sectionalizers, which can act as means which are similar to interacting capability. So, this is called SCB. So, this forms a community microgrid where we have own generation as well as own loads ok.

Similarly, this forms another microgrid and this also forms another microgrid. So, this feeder consists of feeder B, consists of three independent microgrids ok. So, if they are connected usually, but even though the there is any issue with this circuit breaker or any fault in any other feeder section base.

Basically this two SCB makes this particular feeder into 3 sections. This SCB splits this particular feeder into 3 sections and if there is any fault, any issue with one particular section, this microgrid can isolate itself from this particular feeder and they can operate independently.

So, that is what the main difference of this passive network and an active network. Similarly here also in feeder C we have this is one microgrid, one another microgrid, another microgrid. So, this SCB stands for sectionalizing circuit breaker which is having interacting capability or switchable capability similar to a circuit breaker.

But as you know the normal sectionalizing switch they cannot interact while they are only operated in no load condition. But this SCB can operate in the on load condition.

So, this is an example of typical active distribution network consisting of few microgrids, connected to different feeders.

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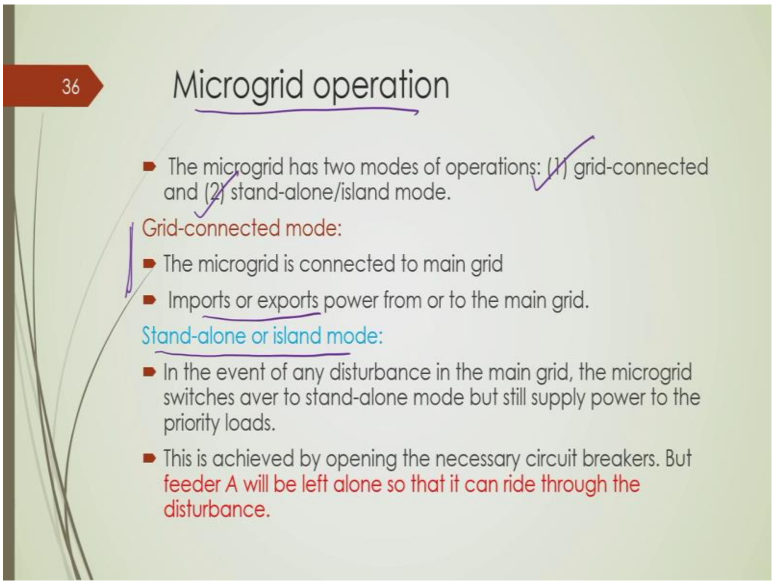

Now, as I said microgrid can be operated either in grid connected mode or stand alone mode. Normally they are operated in grid connected mode and they can import and export power from and to the grid. But, it is possible to operate them in standalone or islanding mode whenever is required when it can be required.

Particularly if there is any fault in the upstream section or is there any grid disturbance and a curtailment of the load from this particular substation to which this particular feeder consisting of microgrid is connected to ok, now, this stand alone mode in the event of any grid disturbance the microgrid switch over to stand alone or islanding mode. And therefore, it will supply their own load from their own available generation ok, but this is possible by opening the circuit breaker ok.

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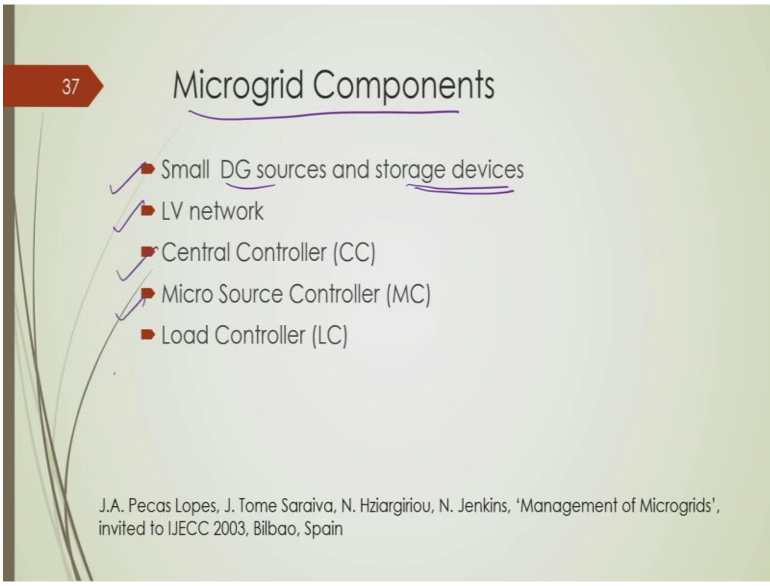

Now, a typical microgrid consists of some of the important components, some of the important building blocks, you can say. One is called of course, small or micro-level distributor generation sources and also storage devices if available also a LV network low voltage network, a central controller, a micro source controller and load controller ok.

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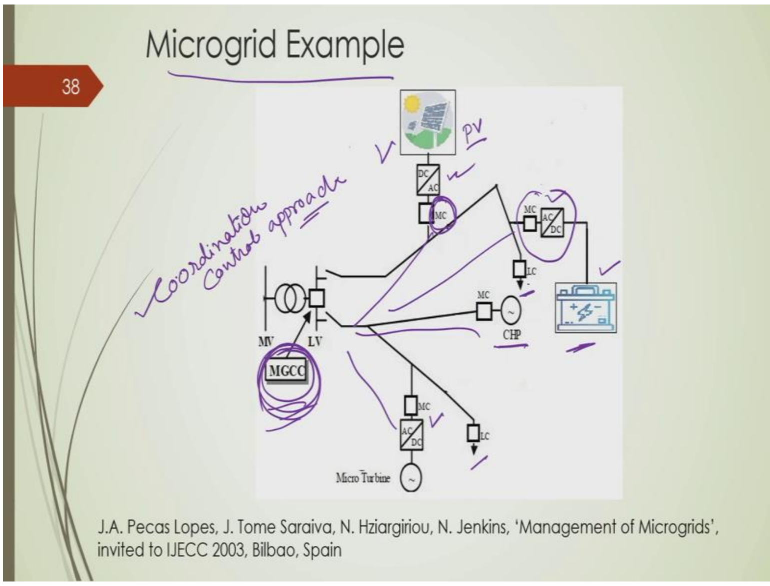

So, this is a typical microgrid. This is itself a complete microgrid where we have here central controller and there micro controller which exist in different sources which is called as micro source controller in different sources. For example, here we have photovoltaic P source. So, it is connected with the conventional microgrid with this converter, DC/AC converters. Here we have some storage connected to this system with this MC controller. Here we have combined heat power generation unit. Here we have another micro turbine and we have some loads specified over here ok.

So, the main purpose of this individual location controller is to control that individual low entity. For example, this controller will basically control the available generation of this generation cannot be controlled, but if generation set point can be controlled ok. So, similarly this controller will control this battery charging discharging this storage charging discharging and so on. But all these controllers will get set point from this central controller which is located here.

This is the central controller and accordingly there is they are used to have a coordination control ok. And based upon this coordination control we write it so we have coordination control approach. And there are several work on work is going on this coordination control approach to control the individual microgrid controller, individual microgrid controller from the centralized controller.

And since all these things will be in the very vicinity within a small geographical locality within a few meters away to each other, so, it is very easy to collect data and to communicate to the controller to the set point.

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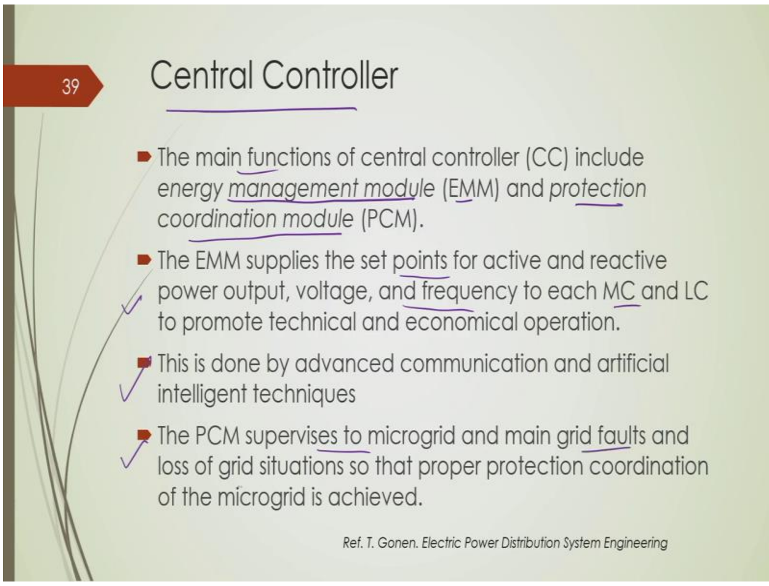

So, the purpose of the central controller includes, the main function includes energy management module that is EMM and protection coordination module. So, basically the centralized controller is responsible to control the energy management and also to control the protection or also to supervise the protection coordination ok.

So, in EMM the set points of this active and reactive power output voltage frequency to each MC and LC are to be provided from this centralized controller. This is done by advanced communication and AI techniques, artificial intelligence techniques, or may be advanced control approaches ok. And this protection coordination module supervises this each microgrid component in case of any faults or loss of grid or grid disturbances ok.

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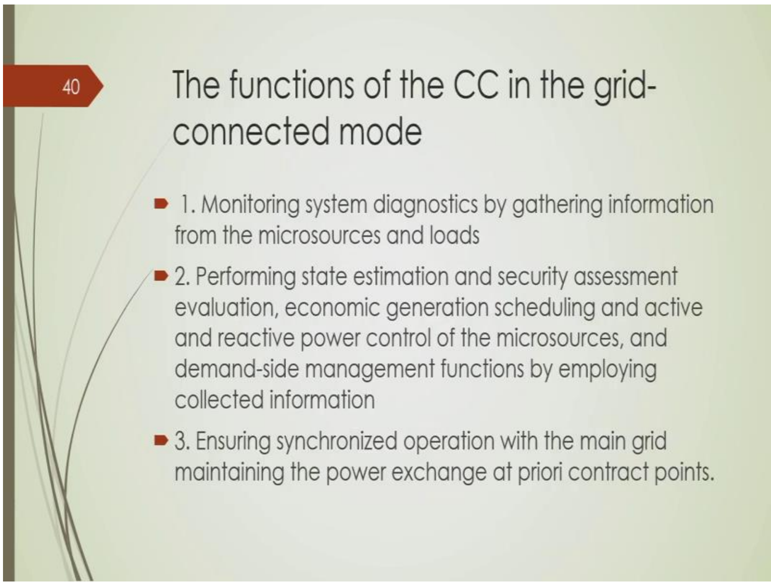

Now, further, there are some functions of centralized control. Central controller in case of operation of grid connected mode gathers information from micro sources and load to perform state estimation and security assessment and to ensure the synchronized operation of the main grid with this particular microgrid.

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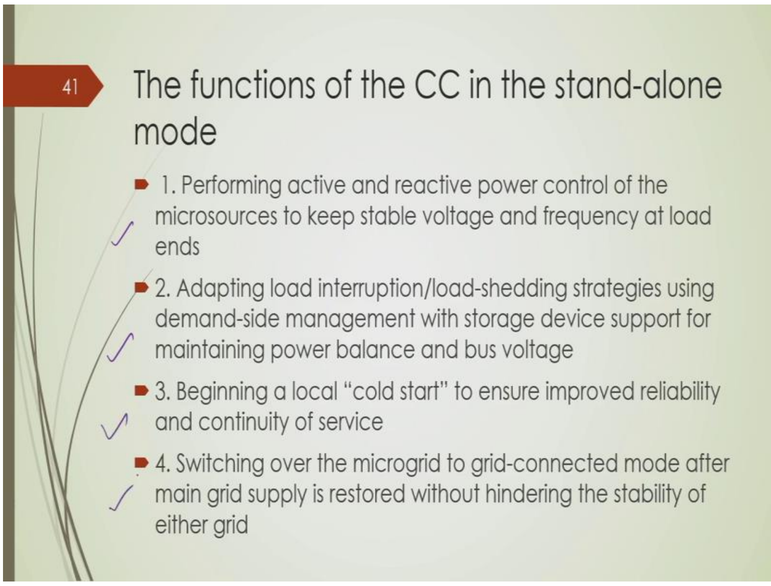

Also there are some other functions like performing active reactive power control, adapting load interruption or load shedding strategies, and to operate during cold start and switching ok.

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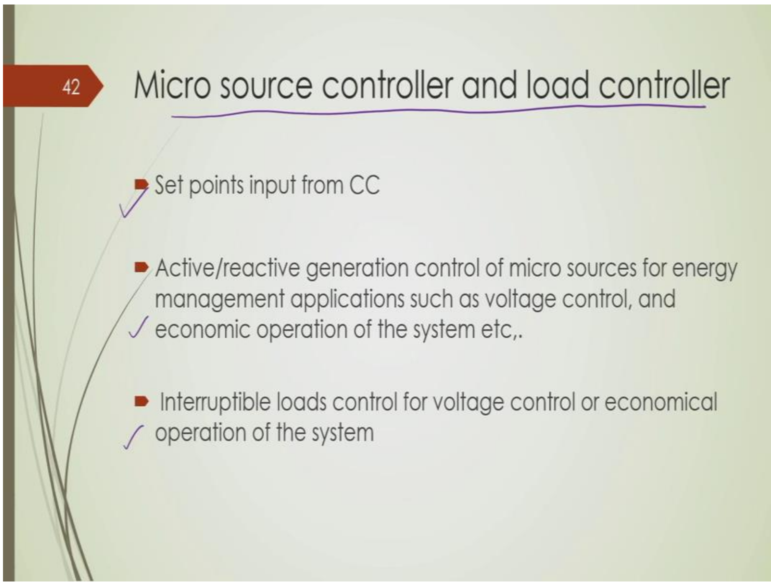

So, these are the functions of micro source controller and load controller to get the set points from the central controller and accordingly to set this active and reactive power generation of the microcontroller sources ok. And also, this interruptible load can be controlled according to a given strategy.

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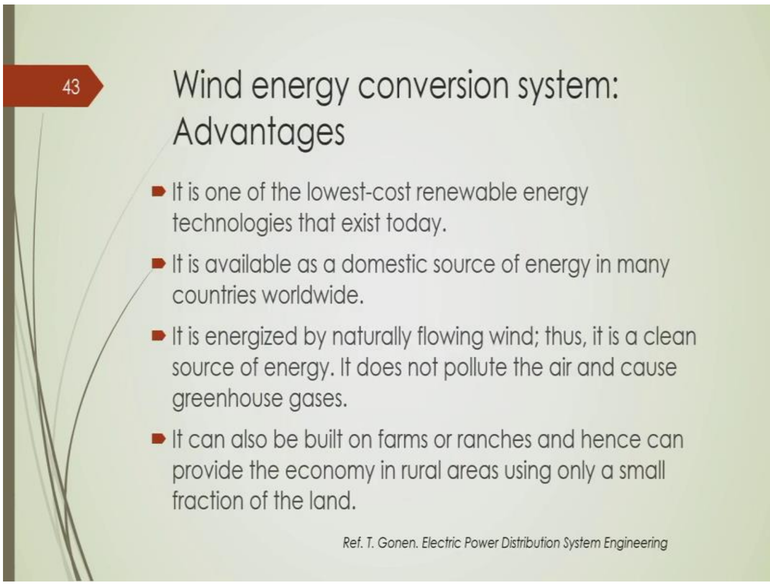

Now, with this, I will basically complete this microgrid concept in brief, but there are some many challenges involved. In fact, control of the microgrid has another domain to work on; another is the coordination control to determine these set points through some approaches.

So, these are upcoming research areas and people are working last few years on it ok. Now, some few minutes, I will spend with two important renewable energy sources to discuss the some two important renewable energy sources. One is called wind energy conversion system, another is photovoltaic conversion system.

Now, wind energy conversion system having many advantages which include effective cost. Many countries have a good wind potential and major part of their generation comes from this energy itself in some of the European countries and we have this availability of wind worldwide and it will not pollute the air and or causes any emission. So, it can be integrated to the rural areas to improve the power supply.

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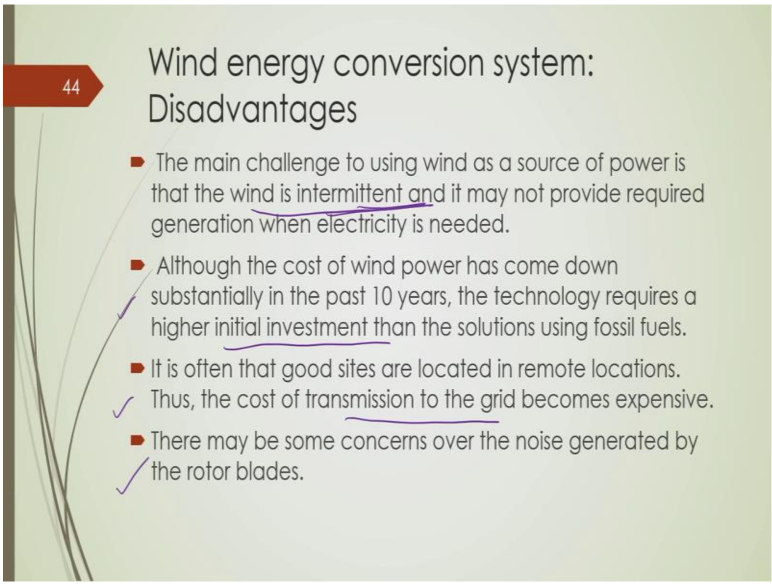

But, there are some challenges as well; firstly wind is intermittent ok. So, there is an intermittency of the generation and variability of the generation for wind energy system ok. So, cost of the wind power particularly has come down last few years last 10 years and so but it requires initial investment cost which is much higher ok.

So, we have some good sites in the remote location, but the cost of transmission to the grid becomes expensive. So, sometimes we have offshore wind park, but again this transmission of power will require some transmission infrastructure which would be making that whole things costlier ok. And also some noises problem is there; some nuisance due to this rotor blades move movement.

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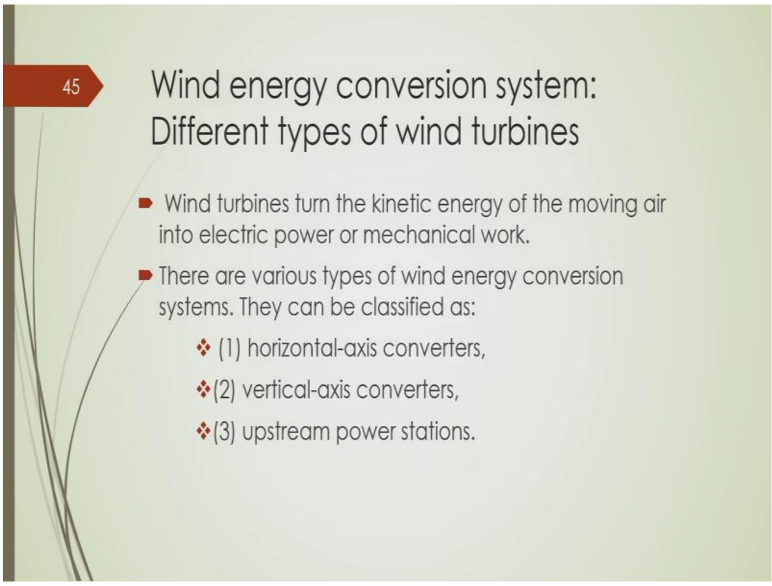

And some small amount of environmental impact due to those types of problems is there. Now, we have different types of wind turbines and they can be classified as horizontal axis converters, vertical axis start converter, and upstream power station ok.

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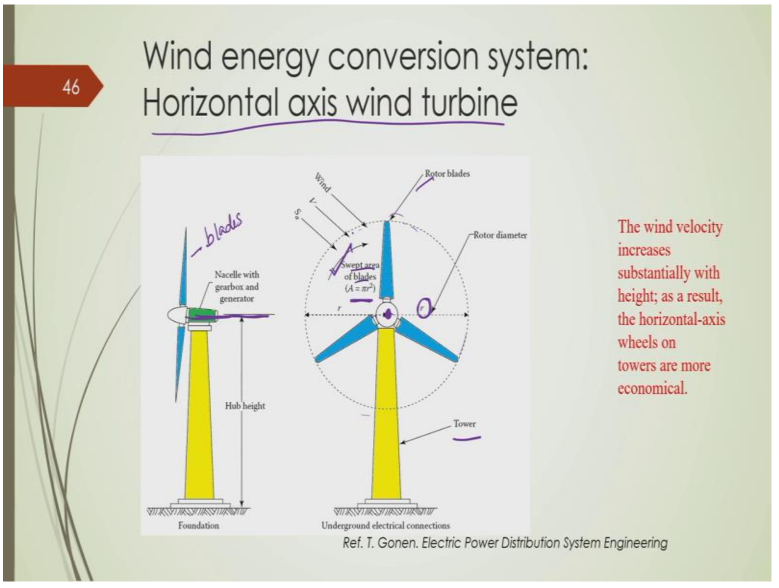

So, this is a typical horizontal axis wind turbine where you can see the axis is horizontal. This is the wind turbine whose axis is horizontal and these are the blade, these are the blades for this wind turbine. So, here it is typical 3-blade wind turbine with a modern design is shown. This is tower, these are the blades and this is the center of this or the axis of the wind turbine from the center this distance is called r.

Then this area which is covered by this dotted line which is nothing but A is equal to pi r square is called as swept area of the blade which is having some significance particularly in wind power generation I will come to that.

So, this dotted line constitutes a circle with respect to the center of the axis of this wind turbine. And if this radius is r which is almost similar to the length of the blade, then this circle constitutes swept area ok alright.

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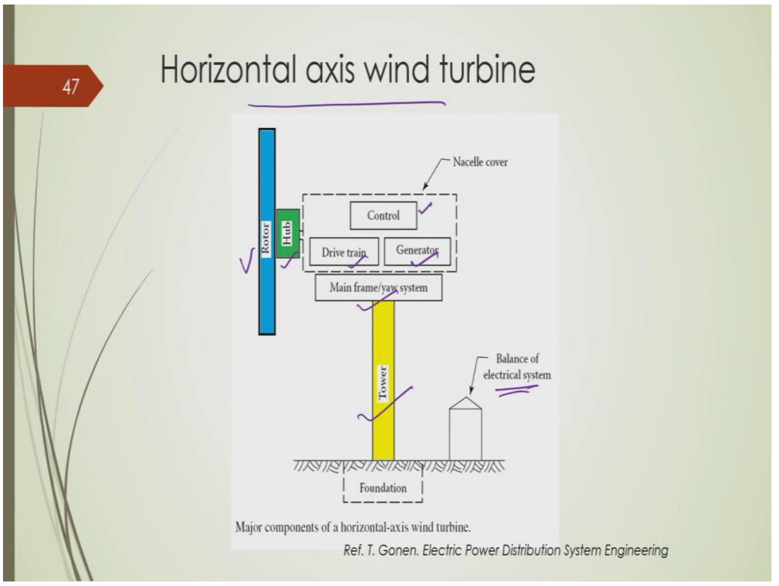

Now, there are many building blocks in a typical horizontal axis wind turbine which includes this rotor of course. Then, this is hub; there are some controllers, controller in-built available there, some drive train main generator. Then main frame or yaw system then, this is founded over a tower and we have some electrical system in order to extract power or in order to bring power from that particular wind turbine.

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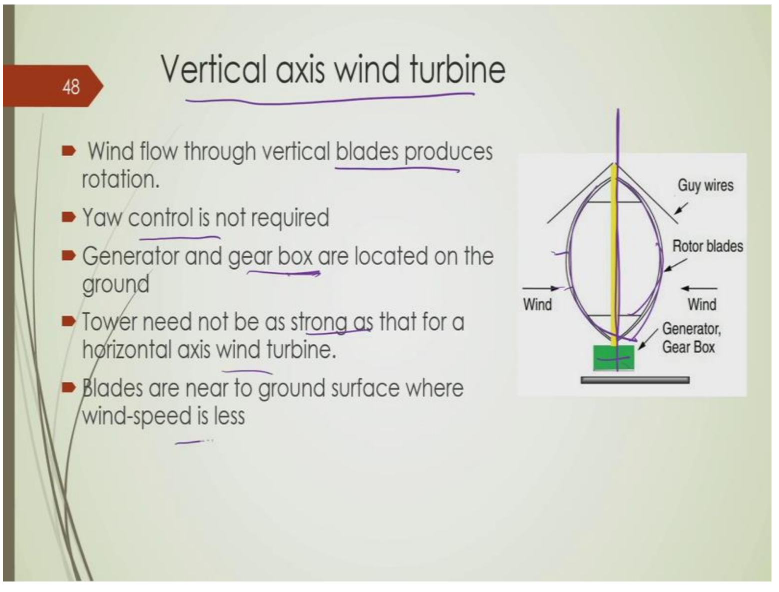

This is a typical vertical axis would in turbine. Here axis is vertical; you can see this is the axis which is vertically placed ok. So, here wind flows through this vertical blades; these are the blades actually, these are the rotor blades, these are the rotor blades and this will rotate with this wind force.

And here it is not to have yaw control yaw. What is yaw control? I will come to that, here generator and gearbox are located on the ground itself here and tower needs not to be strong. Because, it is a horizontal-axis blade near to the ground surface; higher wind speed is less.

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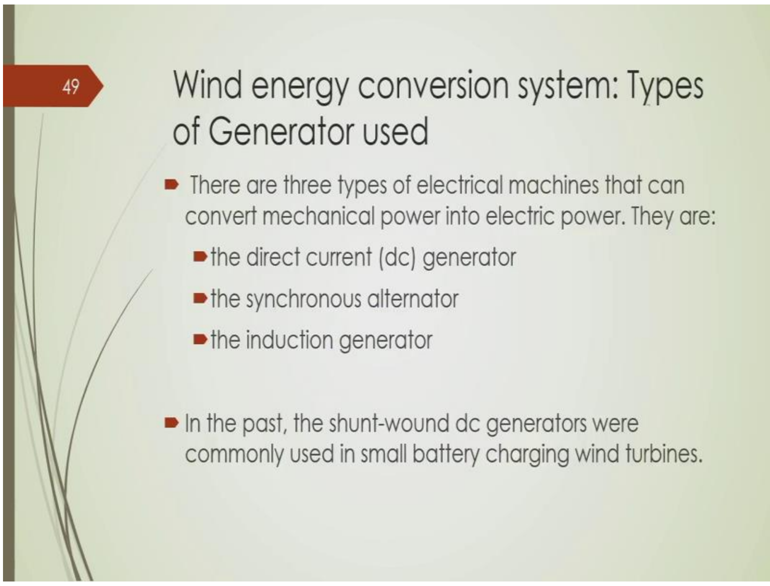

So, we have different types of wind energy conversion systems. Different types of generators used for wind energy conversion system which typically includes DC generator, synchronous generator, or alternator and induction generator ok.

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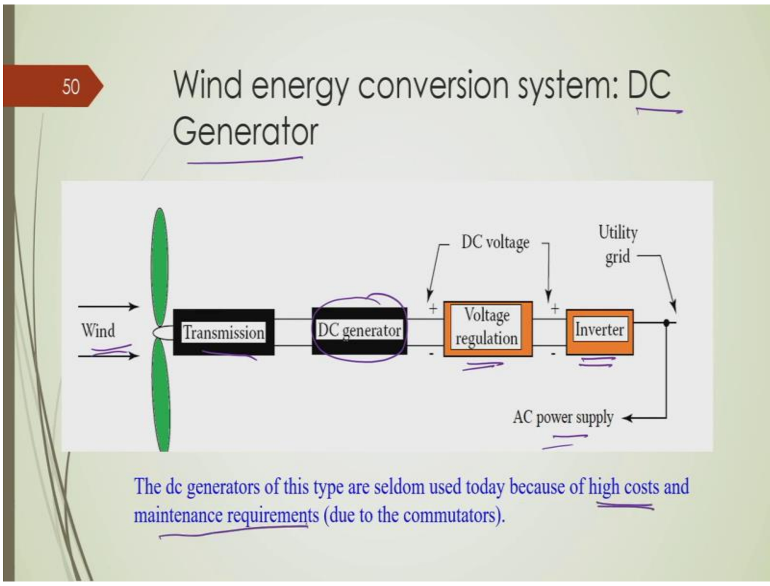

This is a typical DC generator which is not used nowadays, but it was used long time ago when this base operation of this wind mill started with. So, here we have you know this is the power available in the wind; it is extracted and it is being transmitted to this DC generator which converts this to DC voltage.

Then we use some DC to AC converters in order to supply to the normal system our AC system. But DC generators are nowadays seldom used because of this high cost and because of this high requirement of the maintenance due to these commutators.

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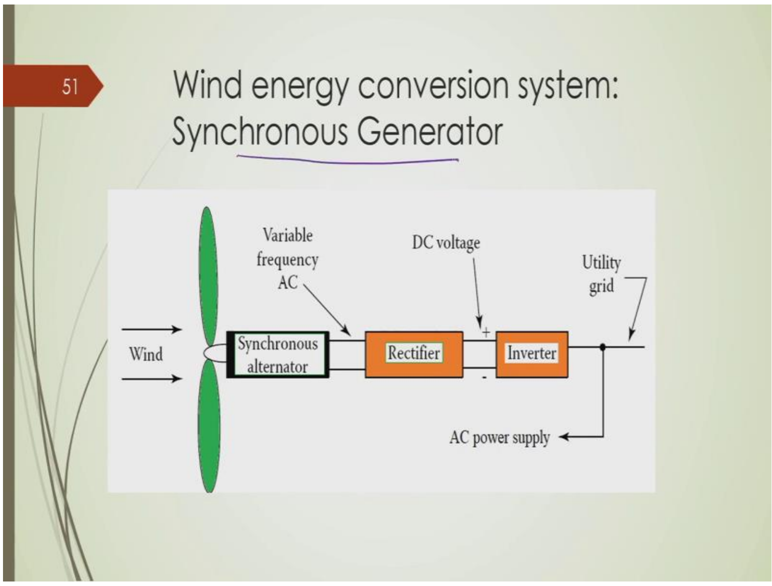

This is a synchronous generator; generally permanent magnet synchronous generator is used and this is the rectifier and inverter unit in order to supply which connects this to the grid with proper synchronized voltage and frequency.

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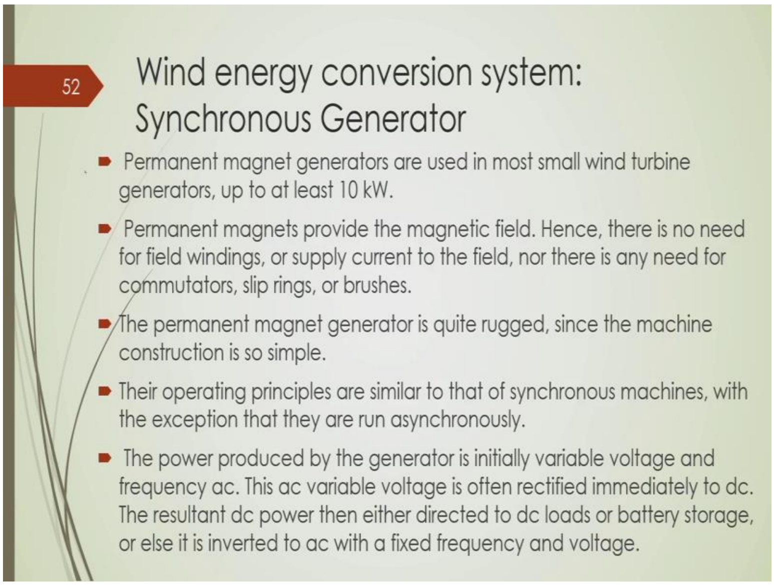

So, basically permanent magnet synchronous generator is used you know in wind turbine for capacity up to 10 kilowatt and so. And you know that what is PM permanent magnet synchronous generator? I am not going into detail of that. It is a rugged, since it is a simple operation, operating principle is similar to the synchronous machine. But here, magnetic field is coming from this permanent magnet ok and it also provides AC voltage. But in order to make it synchronized to the grid, we need some converters which is one AC to DC converter and then further DC to AC converters ok.

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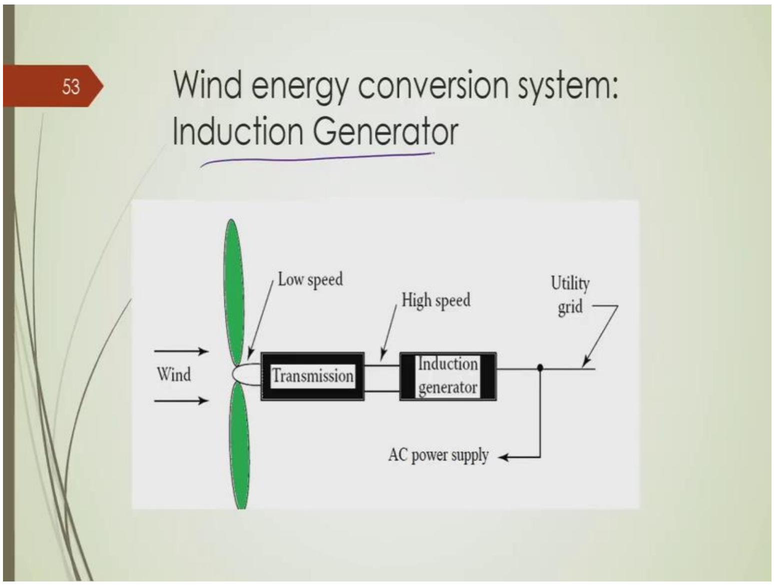

So, this is a typical induction generator type of wind energies conversion system which is similar to this synchronous generator. We have this arrangement same and then we have this induction generator which connects it to the AC power system ok.

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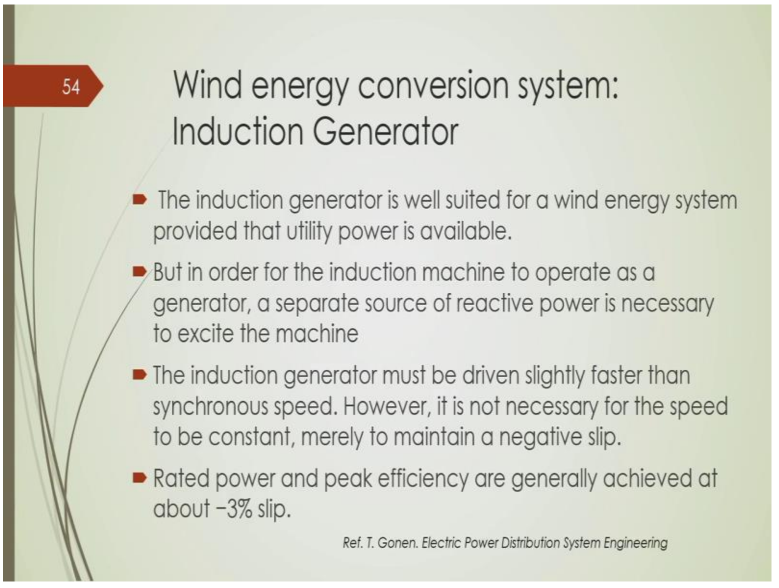

So, induction generator is suited because induction machine is a very popular machine and rugged machine and you know that can be drive even faster than this synchronous speed with some negative slip.

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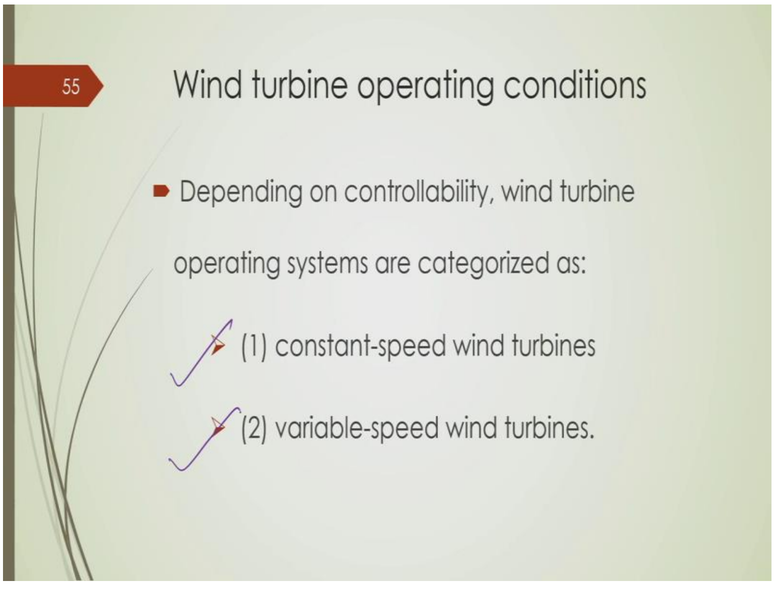

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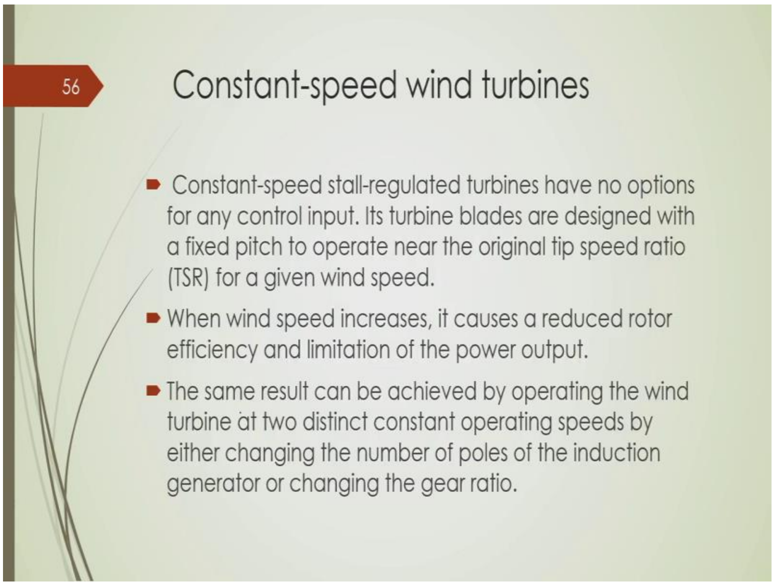

And depending upon the controllability, wind turbine operates in two modes. One is constant speed turbine; another is variable speed turbine in constant speed turbine. It is self-regulated and there is no option of the controlling input ok. So, here basically blades are operated in fixed pitch.

Now what is this pitch? And what is this tip-speed ratio that is TSR? These things I will discuss in the next lecture. So, because of controlling these two, we can extract more energy from this wind or we can have more generation ok.

So, here when wind speed increases it costs reduced rotor efficiency and also the same results can be achieved by operating wind turbine in two distinct constant operating speeds by either changing the number of the poles or in induction generator or changing the gear ratio ok.

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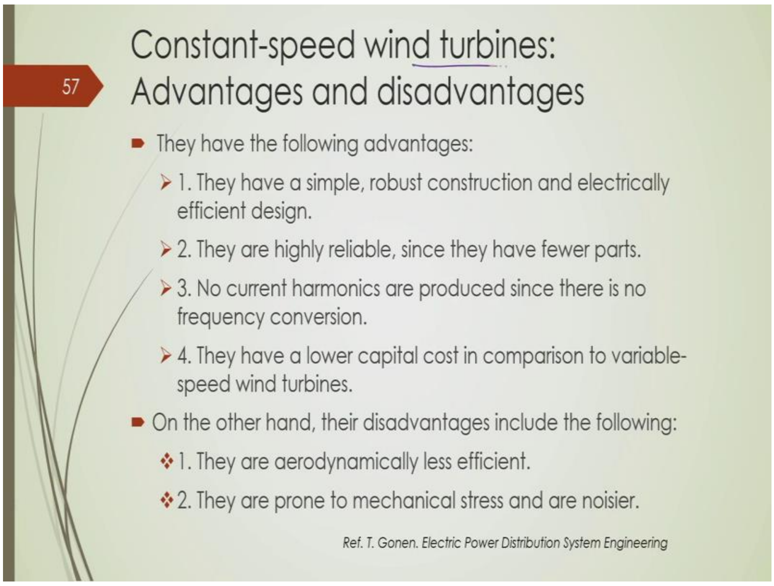

So, for constant speed wind turbine, some advantages and disadvantages are there. These are the advantages. They are simple robust, they are reliable because of few controllable parts and no harmonic produced lower capital cost.

But disadvantage is aerodynamically less efficient because we are not fully utilizing or we are not basically here maximizing the energy extraction which is done in the variable speed of operation I will come to that. So, therefore, they are prone to mechanical stress and noisier.

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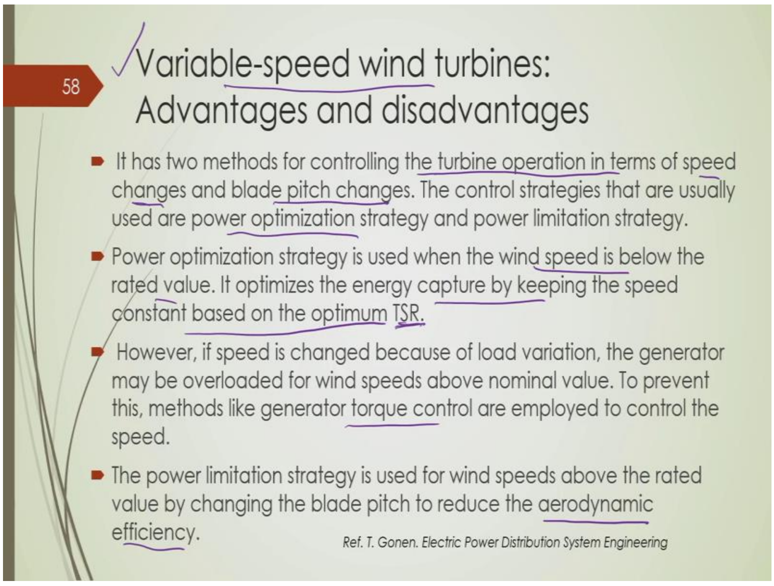

So, in variable speed wind turbines, there are two methods of controlling the turbine operation in terms of speed changes and blade pitch changes. With these two, we can control, we can enhance the generation in different wind speed ok, and we can also make this power optimization strategy ok.

So, when this wind speed is below the rated value we can optimize this energy capture by keeping the speed constant based upon the optimum TSR. TSR stands for Tip Speed Ratio. We will come to that what is the significance of that, but if speed changes with the load variation generator may be overloaded and this prevents the generator control torque. So, these things I will basically discuss in the next class. So, one of the advantages of this variable speed wind turbine is that it is aerodynamically more efficient because we are here we are optimizing the energy extraction ok.

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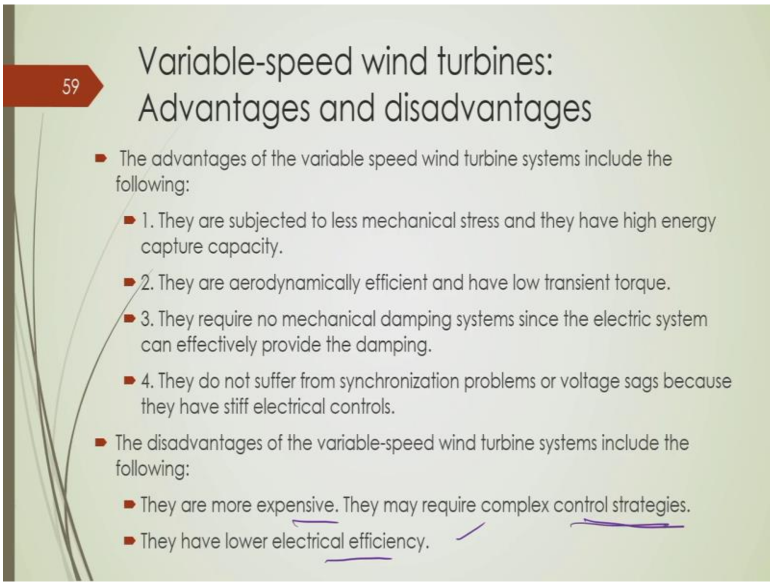

Now, there are some advantages, as I mentioned and disadvantages, as well. We have lower electrical efficiency. And it is particularly more expensive because of some complex control strategies involved, particularly in order to have the effective extraction of the energy ok.

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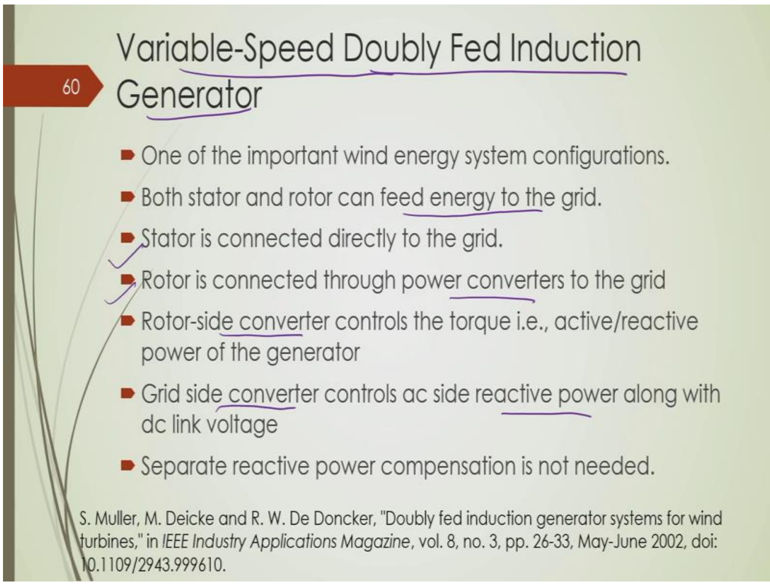

So, presently we have a doubly fed induction generator variable speed doubly fed induction generator which is more efficient and which is mostly used in wind energy conversion system. They are having stator and rotor, both can feed energy to the grid. Stator is connected directly to the grid and rotor is connected through some power converters ok. So, here we have some rotor side converters to control the torque and some grid side converters to control the reactive power along with DC link voltage ok.

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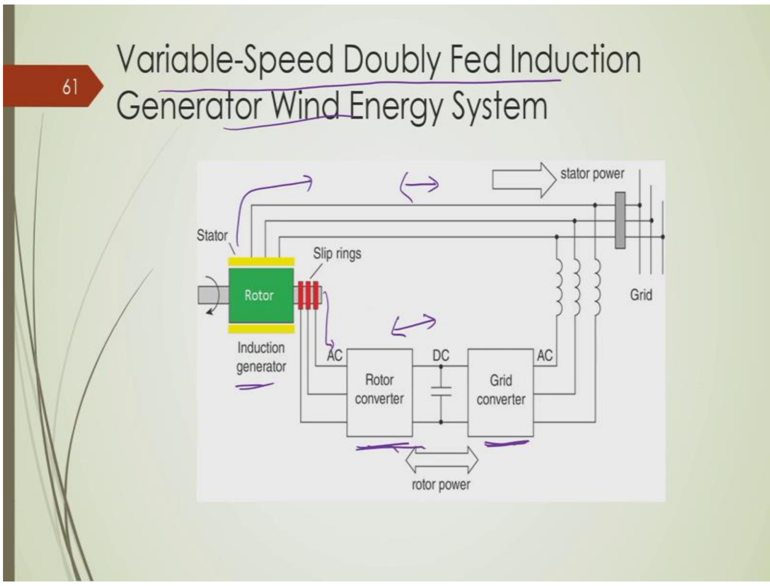

So, the schematic of this is shown over here. So, this is the schematic of doubly fed induction generator which is having two way of power flow. One is connecting with the stator another is through this slip ring through rotor ok. So, here we have two converters this is rotor side converter, this is grid side converter in order to a control the exchange of the power ok. So, it is possible to extract the power, the grid as well as to you know inject power to the grid. Basically, there are four zones of operation for this doubly fed induction generation depending upon the direction of the exchange of the power. So, I am not going into detail. If somebody has some more interest in it they can further explore ok.

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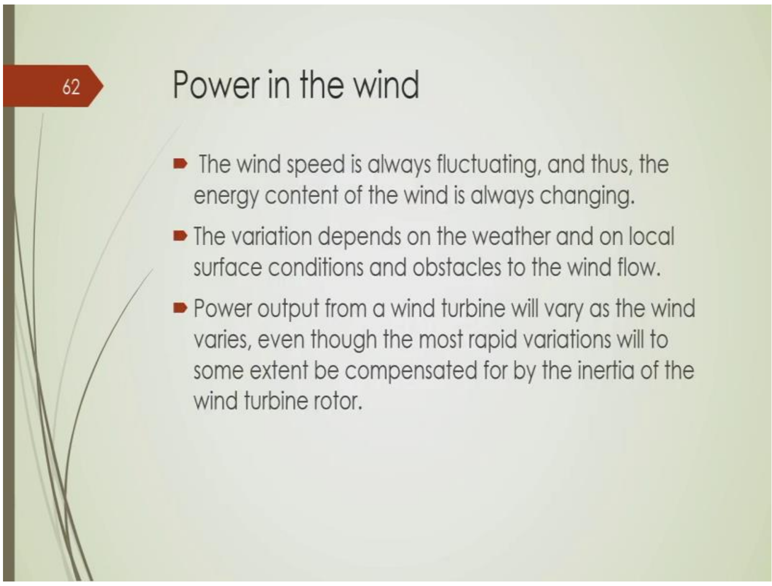

Now, with this I will stop today and in the next lecture, I will complete this part wind energy conversion system. And I will also briefly discuss solar photovoltaic, a type of energy conversion system.

Thank you.